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Coastal Overwash
Part 1: Overview of Processes

PURPOSE

The Regional Sediment Management Technical Note (RSMTN) herein provides information about the causes and process of overwash. Overwash is a form of coastal flooding that can move sediment landward, and it is a precursor to barrier breaching. Washover is the sediment deposited by overwash. Overwash is a regional and recurring process responsible for large-scale coastal change in low-profile coastal areas, and washover is an integral part of the sediment budget in such areas. Subsequent technical notes in this series will present case studies and models under development in the Regional Sediment Management Program for predicting and estimating overwash and washover. A glossary of key terminology is provided at the end of this technical note.

BACKGROUND

Overwash is the flow of water and sediment over a beach crest that does not directly return to the water body (ocean, sea, bay, or lake; hereafter, ocean) where it originated. In the United States, conditions for overwash are most common on the barrier islands of the Atlantic Ocean and Gulf of Mexico coasts, but overwash can occur around the Great Lakes, on low-profile coasts of the mainland, on spits, and on gravel or shingle beaches.

Overwash begins when the runup level of waves, usually coinciding with a storm surge, exceeds the local beach or dune crest height. As the water level in the ocean rises such that the beach or dune crest is inundated, a steady sheet of water (called sheetwash) and sediment runs over (overwashes) the barrier. Overwash is distinct from washover, which is the sediment deposited inland of a beach by overwash. Sediment transported by overwash can be deposited onto the upper beach or as far as the back barrier bay, estuary, or lagoon. Washover can enter channels such as the Intracoastal Waterway, which typically runs parallel to the coast behind the protection of barrier islands and narrow stretches of mainland. Overwash of the mainland deposits sediment landward of the local beach crest. On barriers, seaward-directed overwash may also occur as a result of high bay water level and strong wind creating wind setup and waves incident toward the barrier.

Washover contributes to the sediment budget of barrier islands (Pierce 1969), and overwash is believed to be a major process in the retreat mechanism of some coastal barriers in response to sea-level rise (Dillon 1970; Kraft et al. 1973). Figure 1 shows the result of wide-area landward overwash of Assateague Island, MD/VA, following successive northeasters on 24 January and 5 February 1998. The overwash reached Sinepuxent Bay, located to the west (left side of picture), at several locations. Vegetated

washover deposits from previous storms are evident on the bay side of this barrier island.

Consequences of the inundation, landward sediment transport, and wave attack accompanying overwash are:

a. Loss or damage of property, or loss of access to property, as a result of flooding and sediment intrusion.

b. Burying of, or damage to roads and other infrastructure, and intrusion of sediment in navigation channels.

c. Requirement to remove washover deposits from public and private property to regain functionality of the property. Typically, such deposits are returned to the beach.

d. Loss of protection to the mainland afforded by protective barriers or dunes if they are lowered by overwash.

e. Changes to the natural backshore environment.

f. Shoreline recession and barrier island migration.

g. Increased susceptibility to breaching.

Severe overwash primarily occurs in association with a large storm or a hurricane. In addition to damage caused by sand and water washed onto coastal property and infrastructure, erosion of the beach face can weaken the coast. If the dunes are destroyed or weakened, storm-protection functioning of the beach is degraded. Overwash can be a precursor to breaching by initiating erosion of the beach face, lowering the crest elevation of the beach profile, and transporting sediment from the beach and back beach into the bay (Kraus et al. 2002; Kraus and Wamsley 2003). Where washover reaches the back barrier bay, sediment can enter navigation channels, requiring increased dredging.

Overwash is a natural process, and new washover areas sustain unique ecosystems, such as salt marshes which support various species of salt resistant plants (*halophytes*) (Godfrey and Godfrey 1974) and the habitat necessary for piping plover (*Charadrius meloduso*), an endangered species along the Atlantic and Gulf coasts of the United States as well as regions of the Great Lakes coastal shoreline. On a pristine coast, overwash and wind-blown sand are the mechanisms by which the barrier islands migrate and, possibly, how the barrier islands respond to sea-level rise. Dolan and Godfrey (1973) compared the response of a stabilized (artificial dunes of sufficient height to restrict overwash) and unstabilized barrier shoreline to a hurricane. Although the unstabilized coast was overwashed, lowering the dune crest and moving it shoreward, this section of the shoreline maintained a broad beach. In contrast, the stabilized shoreline lost most of its beach sediments offshore. To address the conflicting demands of environment enhancement and preservation, staff members of the Assateague Island National Seashore of the National Park Service (NPS) and the U.S. Army Engineer District, Baltimore, are designing a protective berm along a portion of Assateague Island that will retard breaching, but allow overwash every few years to provide habitat in the washover.

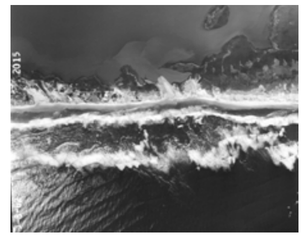
Overwash and washover are, therefore, phenomena to be examined in the coastal storm-damage reduction, navigation, and environmental restoration and sustainability missions of the U.S. Army Corps of Engineers. The catastrophic nature of overwash, and its frequent occurrence on some areas of the coast, indicate that where these processes occur, they must be accounted for on the project level and in long-term regional sediment management. At the same time, predictive technology must address the need to prevent or limit overwash.

EXAMPLES OF OVERWASH

Overwash occurrences are frequent and well documented along the barrier island coast of the eastern states and the Gulf coast. These overwash events are caused by northeasters (winter cold fronts), hurricanes, and major tropical storms (summer and autumn). In some areas, overwash occurs several times a year, whereas in other areas, overwash occurrence is only associated with large storms. Selected storms that resulted in overwash are discussed in the following, in terms of both forcing and response. Not all overwash events are as disastrous as those discussed in the following paragraphs. Smaller events occur with higher frequency, typically on low-profile sand spits and barrier islands where the dunes are low or absent.

Ash Wednesday Storm, 1962

The Ash Wednesday storm of 6-8 March 1962 is a well-documented historic storm that caused widespread overwash (see *Shore & Beach*, 30 (1), 1962), for several articles on damage from this storm). A northeaster associated with three different pressure systems remained almost stationary along the coast of Wallops Island ,VA, for almost 2 days or five high tides. Combined with simultaneous spring high tide, storm surge levels were more than 2 m above normal. Average penetration of washover inland from the beach was almost 300 m, with maximum penetration of about 700 m , and depth of the overwash deposits estimated to be in the order of 0.5 to 0.7 m (Morton et al. 2003). Washover was also observed on the mainland shorelines of New Jersey, Delaware, and Virginia, although to a lesser extent. Coastal foredunes were subjected to long durations of wave attack and eventually destroyed. Back-beach elevations were subsequently reduced, allowing widespread sheetwash to occur along the barrier coasts between Connecticut and North Carolina. The Westhampton Beach field of 15 groins was constructed in 1966 and 1970 in response to weaknesses of the Long Island, New York, barrier chain (Figure 2) created by overwash and breaching during the storms of 1938, 1944, and the Ash Wednesday storm of 1962 (Nersesian et al. 1992).



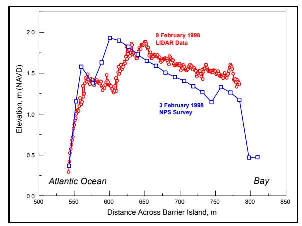
Hurricane Elena, 1985

Significant overwash occurred during the passage of Hurricane Elena, which made landfall on the Gulf Coast near Biloxi, MS, on the 2 September 1985, altering the topography of 300 km of coastal barriers. Maximum wind gusts reached 61 m/sec. On the shorelines of the Chandeleur Islands to the west of the landfall point, strong seaward-directed overwash was observed. The ocean water level in the region of seaward overwash was forced below 0 m National Geodetic Vertical Datum (NGVD) down to a minimum of -0.7 m NGVD when wind was directed offshore (Penland et al. 1989). The Chandeleur Islands are a chain of islands located approximately 96 km east of New Orleans, LA, and 48 km south of Biloxi, MS, and are the remnant of a former Mississippi River delta. The islands afford partial protection of the mainland from storm waves and surge.

Other portions of the Mississippi-Alabama shoreline located to the east of the storm eye experienced beach erosion, sand dune scarping, and shoreward-directed overwash. Washover fans were deposited where higher dunes were breached, and in the areas of lower relief sediment was transported into Mississippi Sound. A peak wave runup of 3.93 m NGVD was measured on this coast. Washover fans were also observed some distance away on the Florida Perdido - Santa Rosa Barrier shoreline (Penland et al. 1989).

January and February Northeasters, 1998

Back-to-back northeaster storms struck the coast of Assateague Island in late January and early February 1998, with wave heights offshore of Ocean City Inlet, MD, reaching 7 m. Most of the northern end of Assateague Island was overwashed (Figure 1), in some places lowering the berm crest 1.4 to 1.1 m. Figure 3 contains plots of selected profiles of the island from a few days before and a few days after the second northeaster. Both the storm berm and dune crest were lowered and shifted landward, and as much as 0.5 m of sand was deposited on the back barrier. Because



of the resulting low crest height, the island was subject to persistent overwash, even after passing of the storm. As a result, an emergency storm berm was constructed over approximately 5.5 km of the lowest part of the northern end of the island to prevent breaching. Studies are being conducted to lower portions of the berm, which has grown in elevation, to allow for periodic overwash, but not breaching.[1]

Overwash of Low-Profile Mainland

Although overwash and washover are usually associated with barrier islands and similar morphologic forms, low-profile mainland beaches can also experience these processes and thus lose sediment from the beach by landward transport. The Gulf of Mexico coast of Jefferson County, TX, running from south of Sabine Pass to Galveston County, provides such an example. A veneer of sand and shell overlays clay, silt, and mud. The flat beach (Figure 4) is backed by pristine wetland, including that of the McFadden National Wildlife Refuge. This beach experiences overwash during tropical storms and hurricanes in the Gulf, causing a portion of the limited sand resource to be moved landward and away from the beach.

OVERWASH PROCESSES

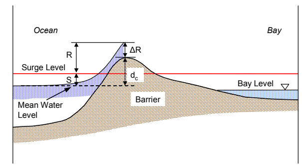
Overwash occurs when wave runup level and/or the storm surge level (water level in excess of predicted tide) exceeds beach crest height. If the storm surge coincides with high tide, the surge level

[1] "Assateague Island, Maryland, Environmental restoration project," Design Report, April 2001. Unpublished memorandum, U.S. Army Engineer District, Baltimore, provided by Mr. Gregory P. Bass.

and, hence, potential for overwash is greater. For moderate storms, it is possible for overwash to occur at high tide and stop during lower stages of the tide, and this depends on the storm surge and elevation and width of the barrier beach. Five different overwash processes are described in the following paragraphs. Any of the processes may occur within one storm, varying both spatially and temporally.

Overwash by Runup

Figure 5 is a schematic cross-sectional view of a sand dune subject to high surge level and overtopping waves. Overwash by runup can be categorized in terms of the relative elevations of water level and the barrier beach, the frequency of overtopping waves, and the excess wave runup, ΔR. The quantity ΔR is the difference between the wave runup height, R, added to the storm surge height, S, and the dune or beach crest height, d_c ($\Delta R = R + S - d_c$)., where d_c is the elevation to the dune crest from the mean water level (or from some common datum).



Overwash by runup can be classified according to the relative magnitudes of $R + S$ and d_c.

(1) $\boldsymbol{R + S > d_c}$ **(infrequent overwash):** If $R + S$ is just slightly larger than d_c, few waves overtop the dune and for those that do, ΔR is small. Leatherman (1976a) observed that for such small-scale overwash, there is negligible transport of sand, but in situ sorting of the sand grains was observed (smaller grains moved landward). Orford et al. (2003) observed for gravel beaches that the smaller overwashing waves

deposited sediment on the dune crest, thus increasing the threshold crest height, d_c, for each subsequent wave and eventually halting overwash.

(2) ***R + S >> d_c* (frequent overwash):** S is still less than d_c, but many waves have sufficient excess runup, ΔR, to overtop the dune. Sediment is eroded from the face of the dune or beach crest and transported to be deposited on the backshore.

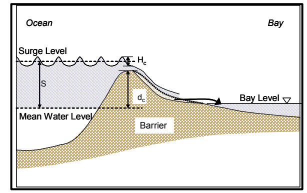
Overwash by Overflow

The third, fourth and fifth types of overwash occur where $S > d_c$. Overwash by overflow can be categorized in terms of the extent of beach inundation and the beach topography. The water and sediment transported landward as a result of the elevated water level and waves is known as sheetwash.

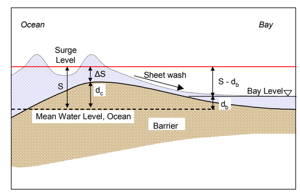
(3) ***S > d_c* (constant flow over the beach crest):** During extreme storms or on low-profile barriers or beaches, S may exceed d_c, and water flows constantly over the beach crest during the time of higher water level. Sediment is eroded either from the beach face and/or the back barrier but either due to beach topography or low S, the overwash may not reach the bay, and washover is deposited as the bore slows. The deposition is usually due to porosity and friction losses as opposed to the lateral spreading seen for sluicing overwash.

(4) ***S > d_c* (constant flow over a prominent dune feature):** Where the back slope of the dune has sufficiently great

gradient and water level in the bay is low relative to the ocean, the overwash accelerates on the back slope causing severe erosion of the dune. This overwash is analogous to flow over dikes or earth dams, which often leads to failure and breaching. The local wave height at the crest H_c may also influence the transport of water and sediment over the crest through its mass flux and additional stirring of sediment (Figure 6). Steetzel and Visser (1992) studied the lowering of the crown of a sandy dam during overflow in the laboratory as a function of dam geometry, grain size, porosity, and the presence of waves. Wave attack led to accelerated erosion and shortened the time scale of the erosion process significantly.



(5) ***S* >> d_c (complete inundation of barrier or spit):** Where the submergence of the crest is sufficient, an entire barrier or spit can become inundated. If coupling between the ocean and bay occurs, it is the magnitude of the water level gradient between ocean and bay, $S - d_b$, that drives the net flow and, hence, the amount of sediment transported (Figure 7). The quantity d_b is defined as the difference between the water level in the bay and the mean water level in the ocean (surge not included). Complete inundation can initiate breaching (Kraus and Wamsley 2003). The action of tide can initiate ebb and flood flow, similar to that at an inlet.

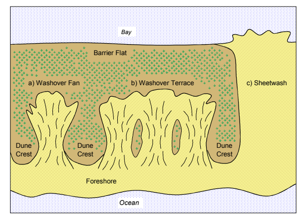


Pirrello (1992) simulated full inundation of a barrier island in a laboratory flume, varying the inundation depth, superimposed wave height, and water level gradient (to simulate water level gradient caused by difference in ocean and bay water levels). For an inundated dune or barrier, the superimposed wave height and the inundation depth were not sufficient to cause significant landward sediment transport. After a cross-shore water level gradient was added, however, a shoreward current was established, and shoreward sediment transport increased. An example of such overwash was observed on the southern end of St. Joseph Island, TX, as a result of 1961 Hurricane Carla. It was estimated that the island was overflowed by 3 m of water together with waves generated in 67 m/sec wind. As a result, the dunes were eroded to sea level and a strong ebb tide carried the majority of the sediment offshore (Leatherman 1976a).

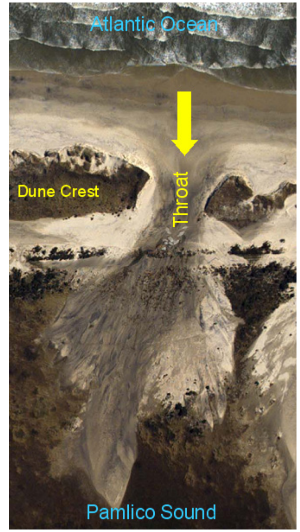
WASHOVER MORPHOLOGIES

Overwash of various magnitude results in different morphological deposits. Figure 8 shows a schematic plan view over a typical dune line subject to overwash with the common overwash deposit types.

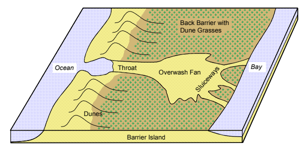
If overwash waves are infrequent and small (Type 1 overwash), only in situ sorting of sediment grains takes place. For Type 2 overwash, which involves more frequent and larger bores, the resulting deposits vary according to local barrier topography and ΔR. Where dunes are relatively high, but uneven, overwash usually exploits existing gaps or lower areas in the foredune line, funneling through the throat of the breach and spreading laterally



on the back barrier. As the water mass spreads laterally, velocity in the bore decreases, and the entrained sediment is deposited. Orford et al. (2003) called this “sluicing overwash.” The resulting depositional feature is called a “washover fan.” In extreme cases, washover fans will reach the barrier lagoon. Figure 9 shows a washover fan on Ocracoke Island, NC, deposited during Hurricane Isabel which made landfall on 18 September 2003. Note the fanning out of the deposit on the back barrier and sand deposited into Pamlico Sound.



If the longshore rate at which sluicing overwash occurs is high, the borders between individual perched fans become less defined, and the deposits form a washover terrace (also washover apron) (Figure 8). Washover terraces can also form where the beach crest is low and uniform. Washover that extends into the back-barrier lagoon appear as a subaqueous washover delta (Leatherman 1976a). Even where a washover does not reach the back barrier, water may run off from the fan to the bay via “sluiceways” or “guts” (Figure 10). According to Leatherman (1976a), sluiceways are small vegetated channels at the water table that convey the water down to the bay, whereas guts are deeper, wet channels that usually form where the fan is non-vegetated or where overwash



has been frequent enough to remove or lay back the vegetation.

For Types 3 and 5 overwash, a longshore segment of beach can be subject to continuous flow of water over the crest which is known as sheetwash. Sheetwash is common on barrier spits and where coastal dunes are low, but it may also occur after persistent wave attack or overwash has reduced the existing dunes to a sufficiently low level. Where sheetwash occurs, lateral spreading is less, and sediment can sometimes be carried and deposited in the back barrier lagoon, an example of which is shown on Assateague Island in Figure 1. Type 4 overwash results in severe erosion of the back barrier and can precipitate breaching or the rapid removal of the dune. Type 5 overwash can either lead to net erosion or deposition depending on $S - d_b$, wind and wave currents, and the tide strength and direction. Type 5 overwash begins the breaching process.

PREDICTION OF OVERWASH OCCURRENCE AND MAGNITUDE

Overwash usually exploits existing discontinuities or weaknesses in the foredune crest line, hence, the formation of the typical washover fan (Figure 9). Greater excess runup heights, however, can initiate gaps in the foredune through which overwash will occur. Spatial variation in dune elevation can, to an extent, serve to estimate spatial variation in overwash events. Wetzell et al. (2003) analyzed hindcasts of extreme wave runup and beach elevation data collected by airborne LIDAR (Light Detection And Ranging) data to qualitatively predict the longshore variation in overwash occurrence caused by Hurricane Dennis on 17 km of the Outer

Banks coastline. Their results were compared with LIDAR surveys collected after the hurricane had passed. Where overwash was predicted, comparisons of pre- and post-storm profiles were consistent with the spatial occurrence of overwash.

Morton and Sallenger (2003) examined the control by various factors on the overwash penetration distance during extreme storm events on both the Atlantic Ocean Coast and the Gulf of Mexico Coast. Surge height, dune topography, and nearshore bathymetry (which all combine to produce an excess runup height) were shown to correlate with penetration distance. Existence of vegetation and confinement of flow were also demonstrated to control the penetration distance. Penetration distance decreased with barrier width, but increased with proximity to open water on the landward side. Therefore, lesser overwash distances are observed on mainland beaches where the foredune topography and surge height is similar to that on a barrier experiencing frequent overwash (Morton et al. 2003).

By analyzing the washover deposits produced by 17 hurricanes on the Gulf Coast, Penland and Suter (1984) showed that the angle at which a hurricane crosses a barrier island exerts some control on the location of peak overwash occurrence. A hurricane that approaches normal to the shore has the highest peak surge and strongest onshore winds ahead of the eye of the storm and to the right of the eye. Thus the greatest overwash occurs to the right hand side of the storm. Occasionally, the weaker offshore winds on the left of the hurricane can cause some seaward overwash, but this is usually followed by landward overwash as the storm passes and onshore winds resume. Penland and Suter (1984) define hurricanes approaching the shore obliquely as either left-oblique impact or right-oblique impact depending on the side the storm approached from (facing the shore). A right-oblique impact is similar to a shore-normal impact, but a left oblique impact can cause significant seaward overwash to the left of the storm because the peak storm surge is lagged behind the storm impact and the strong hurricane winds are directed offshore. These factors combine to give an elevated water level in the back-barrier lagoon and a lower water level on the open coast and, hence, seaward overwash may occur. As the storm passes inland and the storm surge reaches the coast, the direction of overwash can reverse.

Overwash transport and dune profile evolution are difficult to predict, and available algorithms have been based on geometric considerations rather than basic physical formulations. Kraus and Wise (1993) (see, also, Wise et al. 1996) developed an algorithm for simulating overwash by runup over sand dunes for inclusion in the SBEACH numerical model (Larson and Kraus 1989). The model was applied with success to profile measurements made before and after the 4 January 1992 storm at Ocean City, MD. Both the reduction in crest height and thickness of washover were correctly represented as well as quantity and location of offshore transport. The algorithm was originally based on the sediment continuity formula and geometric considerations, and limited physical representation of overwash processes was included. Recently, the algorithm has been updated to include more physically based formulas for sediment transport within the swash zone, across the dune crest, and seaward of the dune crest (Larson et al. 2004). The new algorithm was validated with the previously employed data from Ocean City as well as with data from Assateague Island obtained during the January and February 1998 northeasters (see Figure 1).

OVERWASH AND BARRIER ISLAND MIGRATION

Barrier island migration and the role of overwash in this process has been the subject of debate. One hypothesis is that barrier islands migrate up the continental slope in response to rising sea levels, and overwash is one of the mechanisms by which this occurs. In areas where overwash occurs, washover can be detected by coring. Several authors have studied the sediment budgets of barrier islands to determine the role of overwash in barrier island migration and/or erosion of barrier coasts (e.g., Fisher and Stauble 1977; Godfrey and Godfrey 1974; Leatherman 1976a, 1976b; Leatherman 1979; Kochel and Dolan 1986; Byrnes and Gingerich 1987; Dingler and Rice 1990; McGinnis and Cleary 2003).

It is well established that washover enters in the sediment budget of a barrier island. Overwash can be considered a sink in the littoral system, but the resulting washover is a source to the barrier island sediment budget because it can contribute to the vertical accretion of the back beach. Washover may be deposited in a wetland area, in which case it is removed from the littoral system.

Leatherman (1976a) measured a washover volume of 20 m^3 per meter of overwashed width on Assateague Island following a northeaster. At the same site, Fisher and Stauble (1977) calculated 19 m^3/m for Hurricane Belle, and Eiser and Birkemeier (1991) estimated 20-40 m^3/m on Debidue Beach following Hurricane Hugo. Dingler and Reiss (1990) calculated a total of 14 m^3/m washover over 1 year on the Isles Dernieres. This annualized volume of washover was caused by an unknown number of cold fronts, but demonstrates the reduced overwash capacity of smaller storms. In some cases, wind-blown sediment transport has been shown to redistribute washover sediments offshore (e.g., Leatherman 1976a; Fisher and Stauble 1977), but the existence of permanent washovers both on the surface and in sediment cores indicates the permanence of at least some washovers.

Whether overwash plays a significant role in barrier island migration depends on numerous factors such as elevation of the island, presence of vegetation, sediment supply to the beach, and frequency and strength of storms. Although there is irrefutable evidence that the barriers of the Gulf Coast migrate as a result of overwash that reaches the inshore lagoon (Morton and Sallenger 2003), evidence of barrier migration due to overwash on the Atlantic coast is less certain. For example, despite the extreme conditions and large spatial and temporal range of the Ash Wednesday storm, there was no penetration of overwash to the backbarrier bay, indicating that perhaps not all barrier islands migrate due to overwash (Leatherman 1976b). He also found that for the northern end of Assateague Island, the formation of flood-tidal deltas, often associated with breaching, contributed more to the island's migration than overwash. On the other hand, Zaremba and Leatherman (1984) found that Nauset Spit, MA, migrated with a complete rollover period of 230 years as a result of both inlet and overwash processes. Byrnes and Gingerich (1987) documented rollover, or translation of the low-profile Metompkin Island, VA, which moved landward as a unit under overwash, while conserving mass, during 1985 Hurricane Gloria. It appears therefore, that although overwash is the driving force for barrier migration on some barriers, on others it plays a minor role or contributes mainly to the vertical extent of the island.

RESULTS/ DISCUSSION

Overwash occurs if wave runup and/or storm surge levels overtop beaches and dunes, and can erode sediment from the beach face and crest, depositing it on the back barrier or in the barrier lagoon. It is a common occurrence on both the Atlantic and Gulf barrier shorelines of the United States as well as in the Great Lakes region. Significant overwash usually occurs as a result of tropical storms, hurricanes, and winter cold fronts, northeasters. Washover contributes to the sediment budget of a barrier island, and overwash is sometimes a driving process in the migration of barrier islands landward. Overwash may be the means by which barrier coastlines are preserved through a natural process under the action of storms and relative sea-level rise.

Along developed coasts, overwash can cause damage to infrastructure, property, and even loss of life. Emergency-response costs for an overwash event can include sand removal, rebuilding of a storm berm, dredging of navigation channels, and damage repairs to property.

The extent and magnitude of overwash deposits are dependent on:

a. Storm surge magnitude and duration (which depend on the storm severity and location of the storm eye relative to the beach)
b. Direction from which the storm approaches the coastline.
c. Wave height and period.
d. Tidal phase during peak storm surge.
e. Nearshore bathymetry
f. Beach topography, in particular, barrier width and elevation.
g. Wind direction and velocity.
h. Presence or absence of dune vegetation.

For prediction of overwash due to runup on individual beach profile lines, the SBEACH model can be employed for conditions of either high dunes or low-profile beaches and barrier islands. The modeling requires data or estimates of the beach topography, sediment grain size, and time-histories of surge, waves, and wind. A technical note in this series will describe such SBEACH calculations.

ACKNOWLEDGE-MENTS

Figure 1 (Assateague Island) is reproduced courtesy of Mr. Andrew Serrell, Aero Graphics, Inc., Berlin, MD. Figure 3 (Assateague Island topography) contains data provided by the National Park Service (Mr. Carl Zimmerman) and the U.S. Army Engineer District, Baltimore (Mr. Gregory P. Bass). Figure 4 (Jefferson County) was provided by Dr. Jeffrey P. Waters, U.S. Army Engineer District, Galveston. This RSMTN was reviewed by Dr. Waters and Mr. Bass.

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APPENDIX — GLOSSARY OF KEY TERMINOLOGY

Breach: In a coastal context, a breach is a new opening in a narrow landmass such as a barrier spit or barrier island that allows water to flow between the water bodies on each side. (Kraus et al. 2002).

Hurricane: An intense tropical cyclone in which winds tend to spiral inward toward a core of low pressure, with maximum surface wind velocities that equal or exceed 33.5 m/sec (75 mph or 65 knots) for several minutes or longer at some points. Tropical storm is the term applied if maximum winds are less than 33.5 m/sec, but greater than a whole gale (63 mph or 55 knots). Term is used in the Atlantic, Gulf of Mexico, and eastern Pacific. (CEM)

Northeaster: A northeaster is a cyclonic storm (winds turning counterclockwise) that occurs off the east coast of North America between fall and spring.

Overflow: The flow of water over the crest of a beach where the mean water level is higher than that of the crest.

Overtopping: Passing of water over the top of a structure as a result of wave runup or surge action (CEM)

Overwash: The process where water and sediment flow over the crest of a barrier island, dune or spit by waves and in most cases, storm surge.

Rollover: The flow of sediments from the ocean coast of a barrier to the bay coast. After one *rollover*, the barrier island has moved one times its width landwards whilst maintaining its general cross-shore profile shape.

Run up: The upper level reached by a wave on a beach or coastal structure, relative to still-water level. (CEM)

Sheetwash: A steady sheet of water and sediment overwashing the beach or dune crest as the water level in the ocean rises such that the crest is subject to constant overflow. This is a form of overwash.

Sluicing Overwash: Sluicing overwash occurs when overwash is confined to local dips in the beach crest height. Sluicing overwash leads to the formation of washover fans and terraces (Orford et al. 2003).

Storm surge: A rise above normal water level on the open coast due to the action of atmospheric pressure and/or wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress. (CEM , modified)

Tropical storm: A tropical cyclone with maximum winds less than 34 m/sec (75 mph). (CEM)

Washover: The sediment deposited inland of a beach by overwash processes. (CEM)

Washover Fan: A washover fan is formed as a result of sluicing overwash.

Washover Terrace: A washover terrace is formed when many washover fans are formed so close that their edges become indistinct or when overwash by runup occurs over a low uniform beach.

Figure 1. Large-scale overwash on Assateague Island, MD/VA, following northeasters in late January and early February 1998 (view looking northwest; picture taken 8 February 1998)

Figure 2. Overwash (white sand fans) on eastern Fire Island, 8 March 1962, in waning stage of March 1962 Ash Wednesday storm (north is at top)

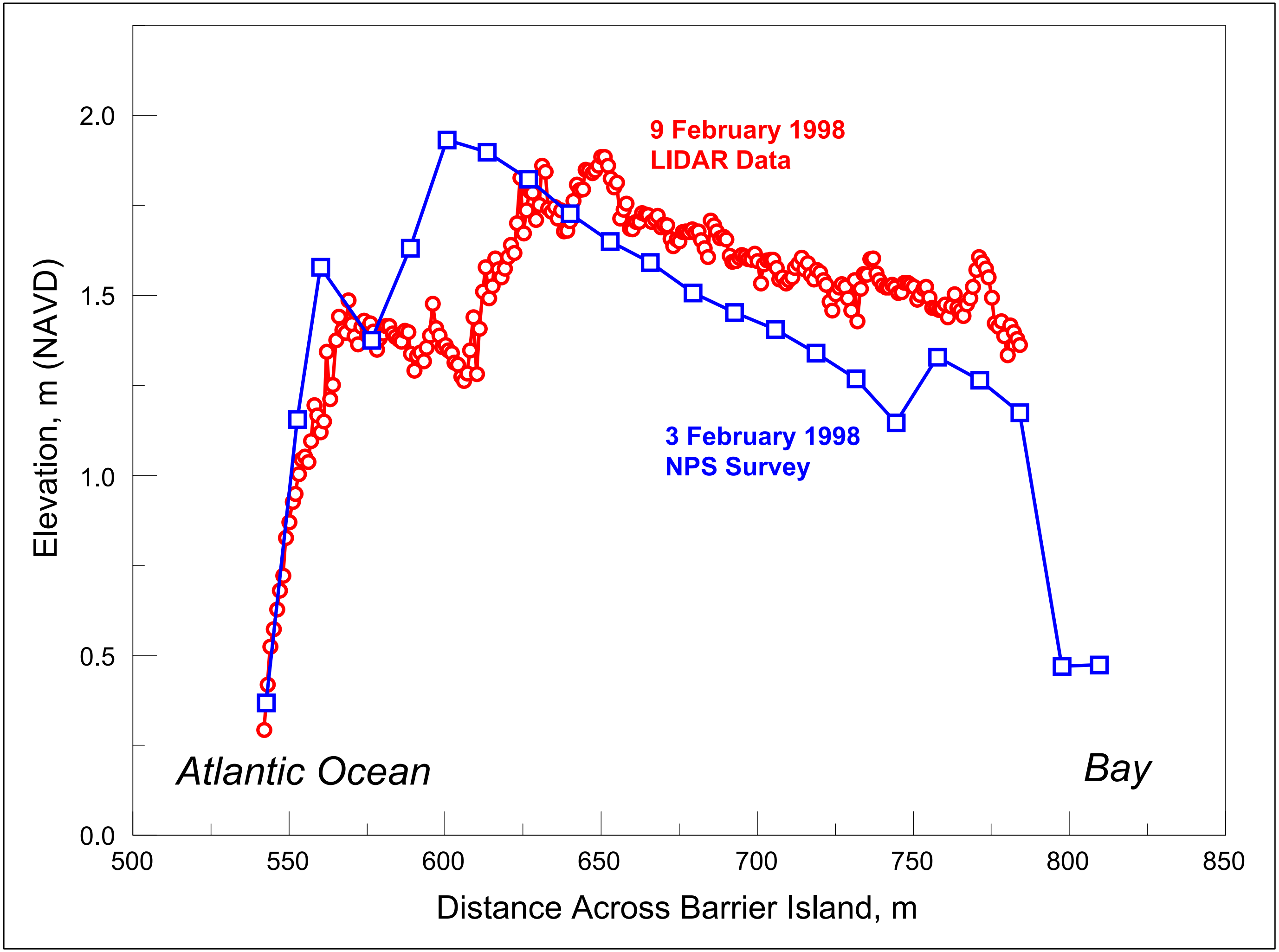

Figure 3. Assateague Island barrier profiles survey prior to and following the January and February 1998 northeasters. The water level for this storm (including surge) was 1.8 m NAVD-88

Figure 4. Beach at Jefferson County, TX (view looking west)

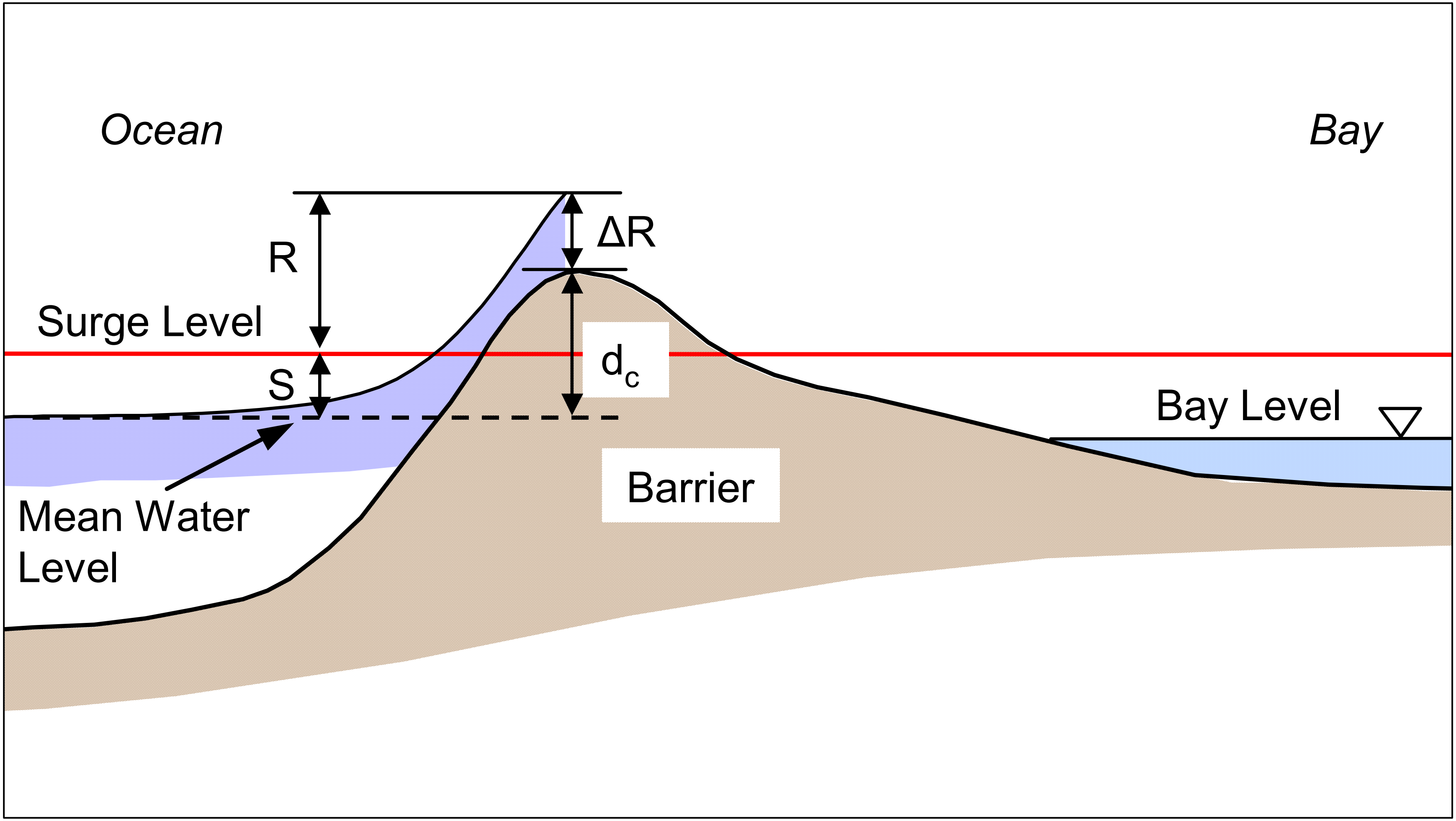

Figure 5. Definition sketch showing the cross section of a barrier beach subject to overwash by wave runup

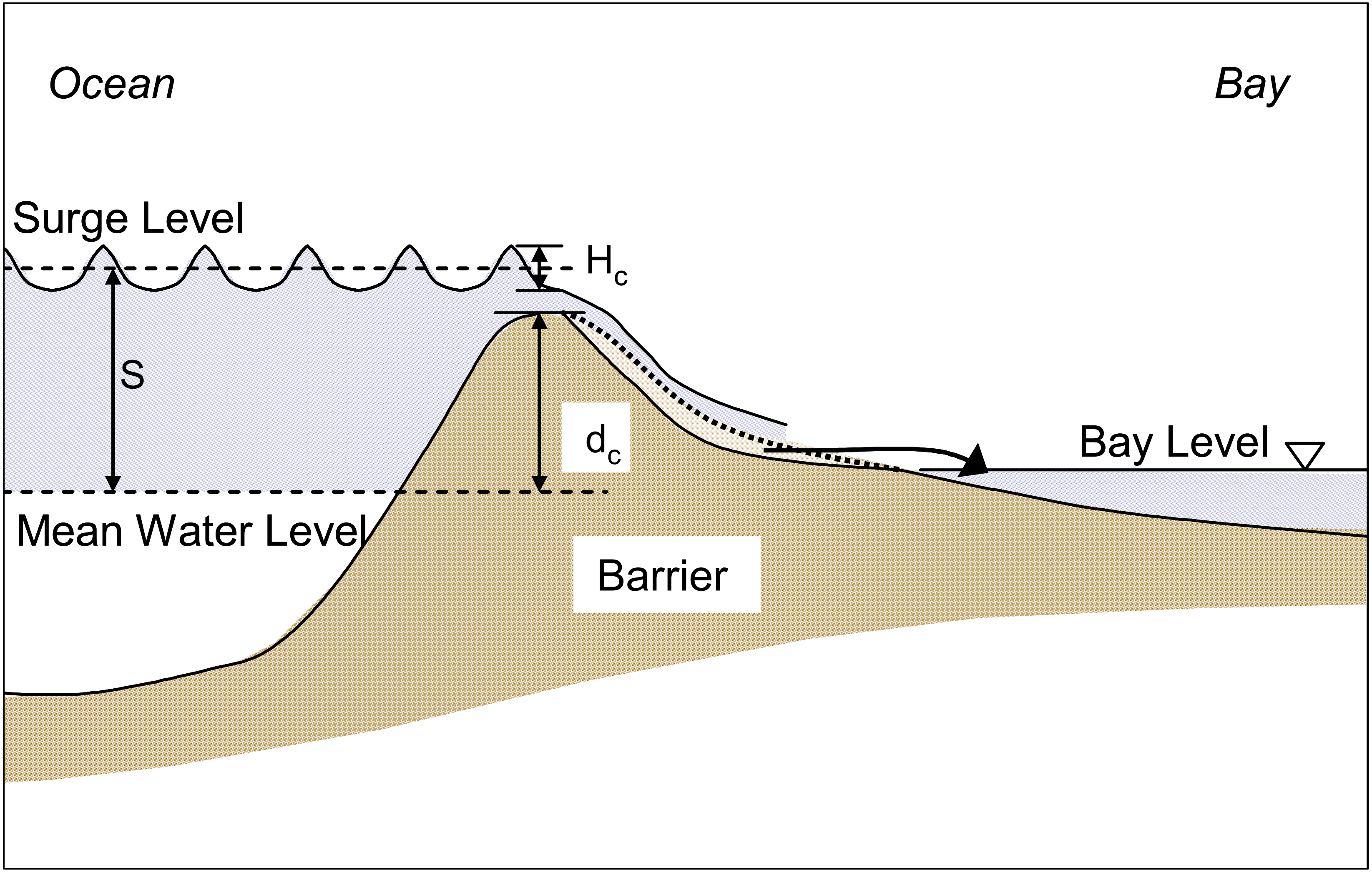

Figure 6. Definition sketch showing cross section of a barrier with a prominent dune subject to overwash by overflow

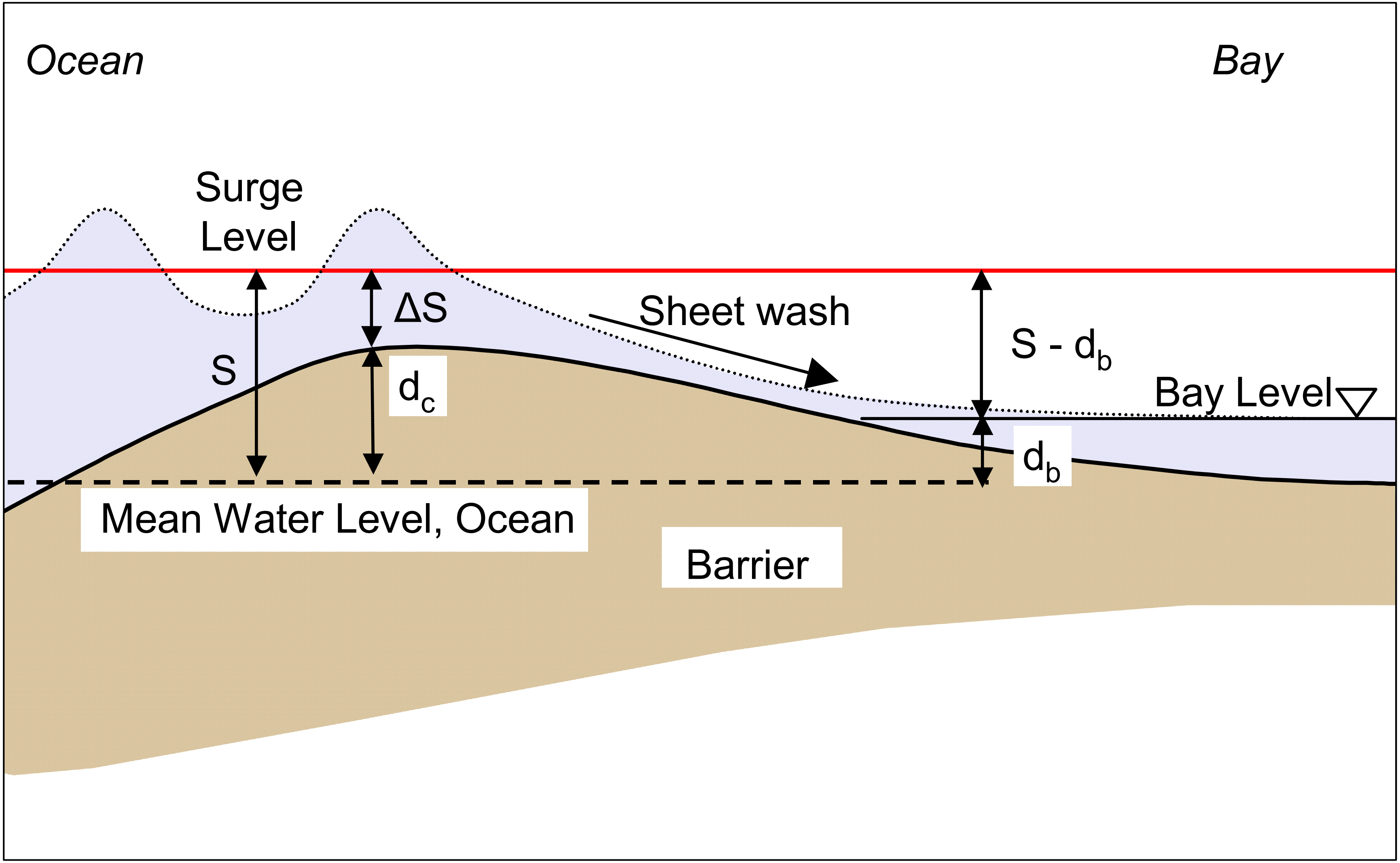

Figure 7. Definition sketch showing cross section of a barrier beach subject to overwash by overflow where barrier is fully inundated

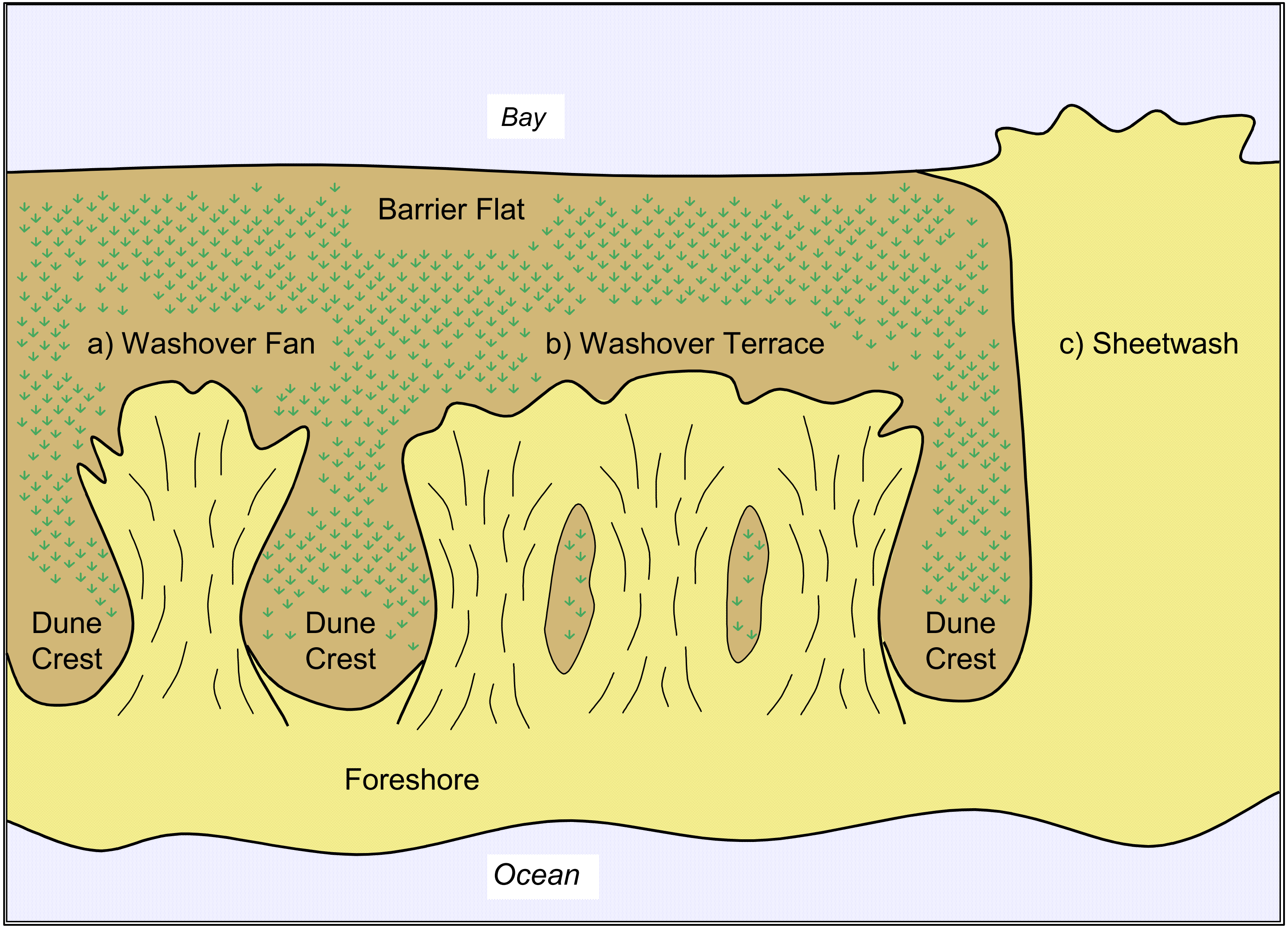

Figure 8. Definition sketch of common morphological deposits occurring during overwash of dunes such as (a) a washover fan, (b) washover terrace and, (c) sheetwash deposit

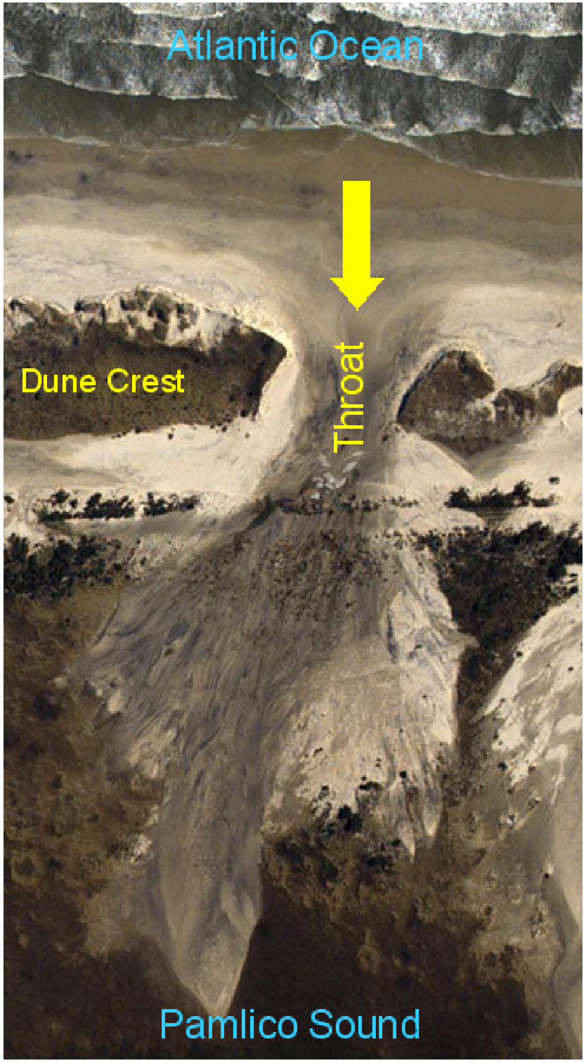

Figure 9. Washover fan deposited on Ocracoke Island, NC, during Hurricane Isabel, September 2003

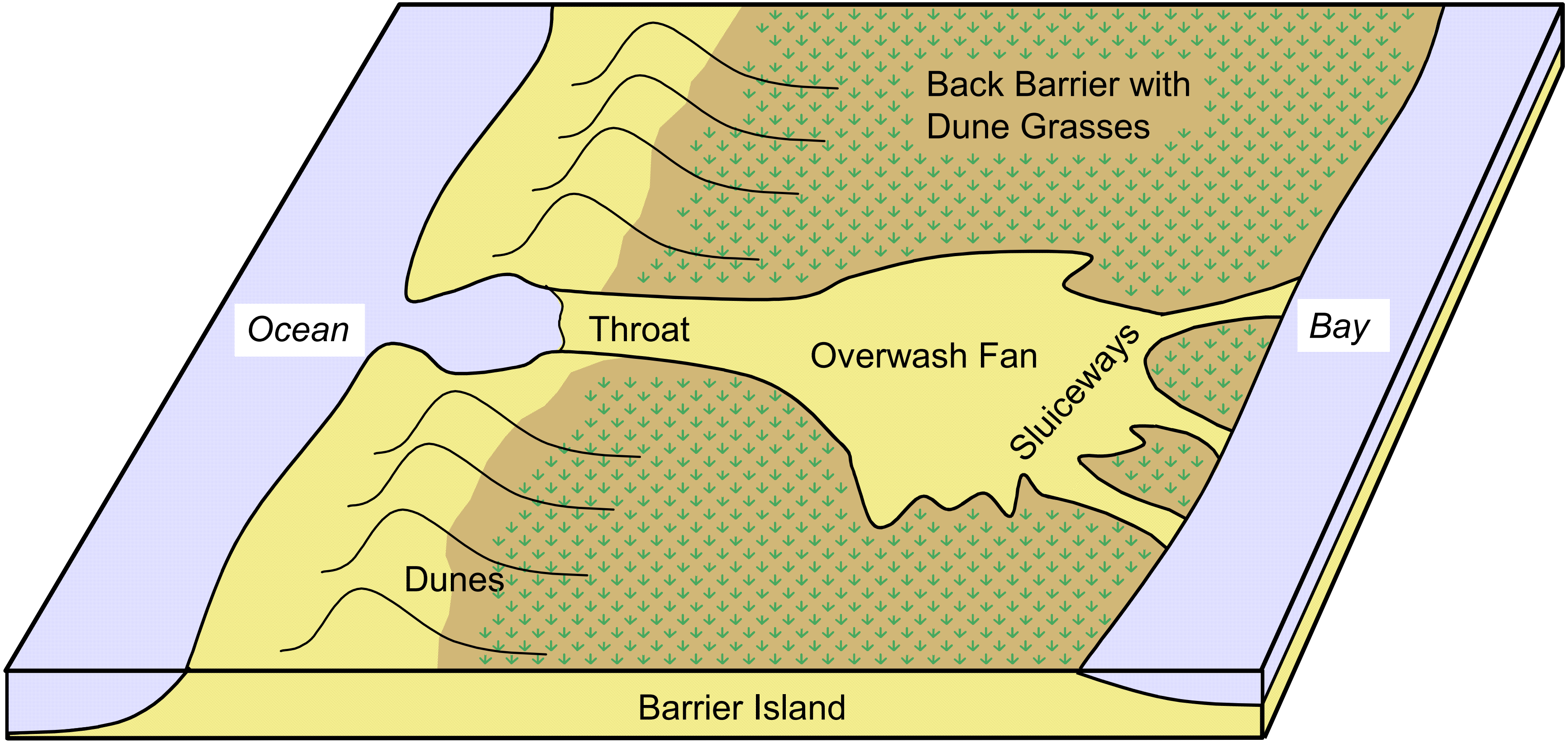

Figure 10. Schematic showing typical overwash fan morphology

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